The MUliple SCattering in Lidar Experiments (MUSCLE) Intercomparison Exercises, and Other I3RC Considerations

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Space & Remote Sensing Sciences Group (ISR-2)
Topics

• MUSCLE
  – what is it?
  – intercomparisons

• Intercomparison overview
  – with a gap to fill?

• 3D RT: Focus on the big-picture
  – where we are, and
  – where to go
MUSCLE

• Origins - 1995, ending with …
  – Lidar-In-space Technology Experiment (LITE) on Space Shuttle in Fall 1994, esp. night orbit #135
  – Applied Optics B Special Issue (5+1 papers)

• 1996 - 2005 period:
  – Quebec City
  – Jerusalem
  – Florence
  – Williamsburg
  – Oberpfaffenhoffen (near München)
  – St. Petersburg
  – Quebec City

• Next?
Bruscaglioni, P.; Ismaelli, A.; Zaccanti, G.,
Monte-Carlo calculations of LIDAR returns: Procedure and results,
Applied Physics B: Lasers and Optics,

Flesia, C.; Schwendimann, P.,
Analytical multiple-scattering extension of the Mie theory: The LIDAR equation,
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Starkov, A.V.; Noormohammadian, M.; Oppel, U.G.,
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Zege, E.P.; Katsev, I.L.; Polonsky, I.N.,
Analytical solution to LIDAR return signals from clouds with regard to multiple scattering,
Applied Physics B: Lasers and Optics,
Volume 60, Issue 4, April 1995, Pages 345-353.

Bissonnette, L.R.; Bruscaglioni, P.; Ismaelli, A.; Zaccanti, G.; Cohen, A.;
Benayahu, Y.; Kleiman, M.; Egert, S.; Flesia, C.; Schwendimann, P.; et al.,
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MUSCLE Comparison Plots
3D RT Comparisons, Compared

- I3RC (deterministic, computational)
- ICRCCM - III (statistical, modeling)
- RAMI (vegetation canopies)
- MUSCLE (localized/pulsed sources)
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• Non-vegetated surfaces?
  – DIRSIG (Rochester)
  – McSCENE (Spectral Sciences, Inc.)
  – Something with radiosity
  – Etc.
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Focus on the Big 3D RT Picture
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<tr>
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- 1D
- 2D
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Atmospheric 3D RT Evolution

1975 - 1995 (and beyond):
3D damage assessment for 1D RT modeling
i.e., uncertainty quantification

Since 1995:
→ damage mitigation (back to 1D, w/o bias)
→ innovation (exploit 3D RT phenomena)
3D Damage Mitigation

- Effective optical depth (e.g., Cahalan 1994)
- Gamma-Weighted 2-Stream (Barker 1996)
- Rescaled optical properties (Cairns et al. 2000)
- Effective optical properties (Szczap et al. ≈2002)
- Nonlocal Independent Pixel Approximation - NIPA (Marshak et al. 1998)
- Etc.
Innovation

• In energetics, this calls for new equations to solve:
  – Markovian stochastic media;
  – Stephens’ (1998b) closure scheme;
  – Power-law propagation kernels, formerly known as Lévy/anomalous photon diffusion model.

• In diagnostics, this means going beyond improved or adapted sampling of photon state-space (wavelength, position/direction, maybe polarization). Uses 3D photon flow patterns and/or population properties.
Innovation, continued:  
*Examples in Remote Sensing*

- Exploitation of radiative smoothing in $R$ or in $T$
- Normalized Difference Cloud Index - NDCI
- “Bright/Dark” radiance ratio technique for dense compact clouds
- Pathlength moments from O$_2$ A-band spectroscopy at fine or ultra-fine resolution
- Large-footprint cloud lidar
  - LITE
  - “in situ” cloud lidar (not “remote” per say)
- Off-beam cloud lidar w/ space- and time-resolution
  - WAIL (at LANL) & THOR (at NASA-Goddard)
“Take Home” Messages

• Verification and Validation (V&V)
  – “solve the equations right”
  – “solve the right equations”

  (Roache ≈2000)

• Work with others …
  – Atmosphere - Ocean - Land - Planetary
    • Modelers
    • Observers
  – Need more/better approximation techniques
  – Outreach & teaching

• Dream up new observations
  – New synergies
  – New instruments